



Johnson Space Center
Engineering Directorate
Software, Robotics and Simulation Division

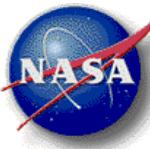
Electronic and Augmented Reality Procedure Technology

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Software Robotics & Simulation Division / ER

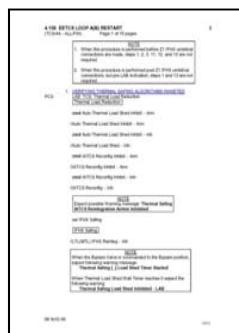
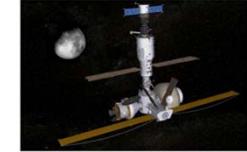
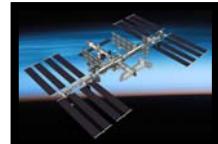
NASA JSC

February 2014

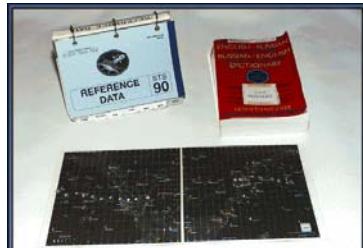


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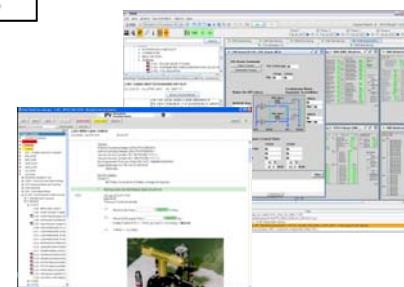
Evolution of Procedures



Early ISS—PDF



Apollo & Space Shuttle—Paper



Current ISS—IPV/XML

- No Automation or Computer Oversight



Orion; Enhanced XML (PRL)

- Computer Oversight
- Automation



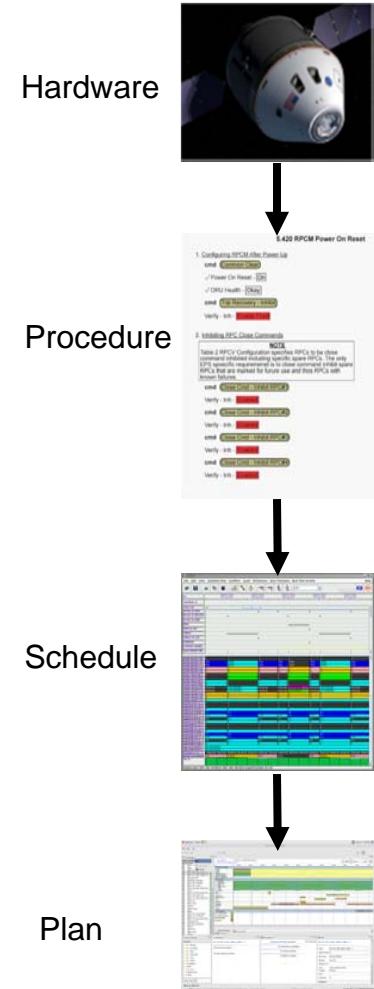
Deep Space Exploration- AR-eProc;

- PRL Extension
- Machine Vision and Marker-less Registration



Background

- Mission Operations: Overview
 - Crew operate equipment using *procedures*
 - Mission Control staff operate equipment remotely using *procedures*
 - Mission Control staff maintain operations *schedules and plans*
 - Staffing, equipment configuration and manifests also require scheduling and planning





Flight Procedure

- Procedures contain knowledge about how to operate systems to achieve mission goals
- Procedures are the approved means by which a user operates a system
- Users of procedures include crew, flight controllers, instructors, mission designers, payload community, etc.

5.420 RPCM POWER ON RESET
(GND SYSTEMS/X2R4 - 12A/FIN 4) Page 1 of 14 pages

1. [CONFIGURING RPCM AFTER POWER-UP](#)

Reference Table 1 for Element RPCM Architecture

Record Element and RPCM from Table 1

Element = _____

RPCM [X] = _____

PCS

Element: EPS

Element: EPS

sel RPCM [X] where [X] is selected from Table 1

RPCM X

sel Firmware

'Clear Cmds'

cmd Common Clear

vPower On Reset – blank

vORU Health – OK

RPCM X

sel Input Undervoltage

cmd Trip Recovery – Inhibit Arm

cmd Trip Recovery – Inhibit (Verify – Inh)

2. [INHIBITING RPC CLOSE COMMANDS](#)

NOTE

Table 2 RPC Configuration specifies RPCs to be close command Inhibited including specific spare RPCs. The only EPS specific requirement is to close command inhibit spare RPCs that are marked for future use and those RPCs with known failures.

Refer to Table 2 for RPC Configuration.

Record RPCs which require Close Inhibits from Table 2.

RPCM [X] = _____

Close – Inhibit RPC [Y] = _____

Element: EPS

Element: EPS



Procedure Requirements

- Need support for automating procedure execution
 - Commands and telemetry
 - Safety conditions/context
 - Explicit control structures
- Don't want to lose human readability
 - Capturing “look-and-feel” of current procedures
 - Presentation of procedure content in a human-friendly way
- Improve quality of execution
 - Improved ease of use
 - Reduction of human error
 - Improved situational awareness
- Interleave human actions with spacecraft scripts
- Use *Procedure Representation Language*
 - Capture and formalized the above stated requirements
 - Started from NASA ODF standards and construct support automation

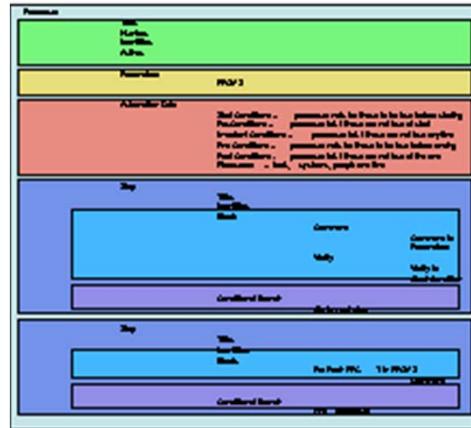


Uses of PRL

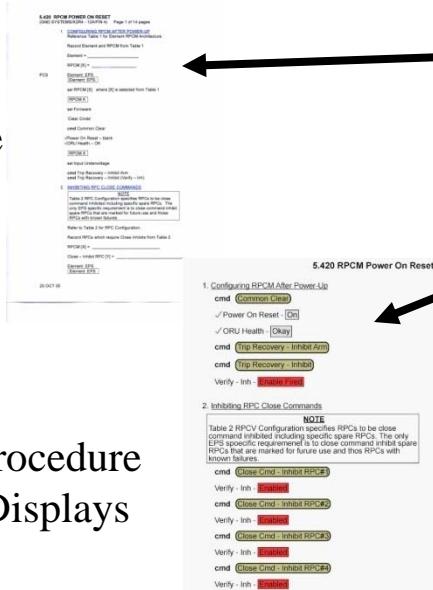


Procedure Authoring Tool (PAT)

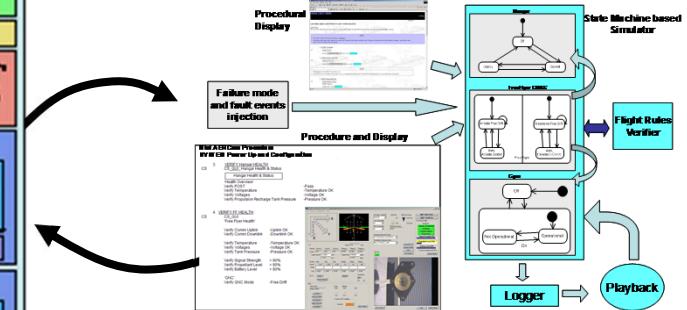
Procedure Representation Language (PRL) file



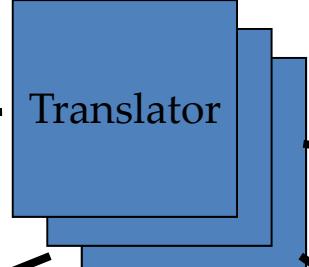
Paper Procedure



Procedure Displays

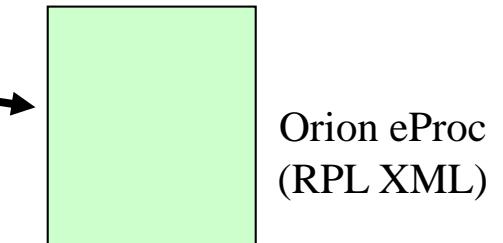


Procedure Verification Tools



Ground Control Tools
(e.g., Thin Layer)

Send
Command foo
Command bar
Wait 10 secs
Command foo2



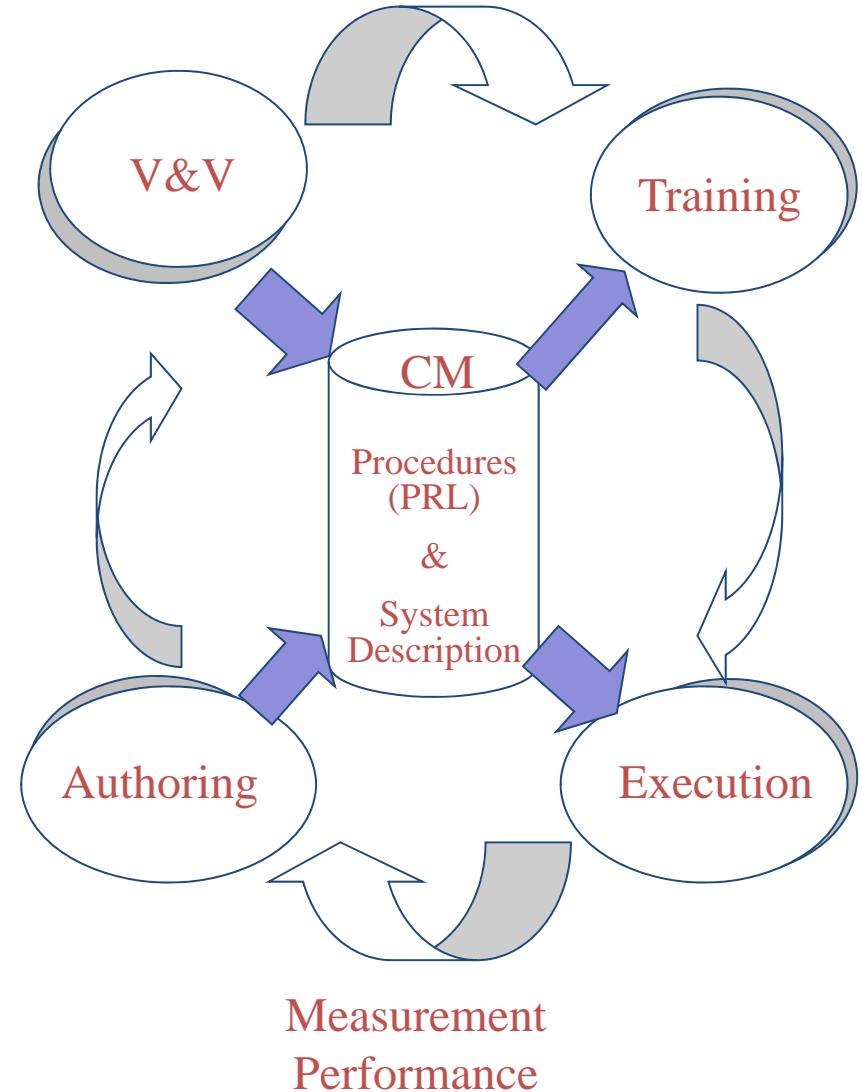
SCL
Execute foo
Verify bar
Wait 10 secs
Execute foo2
End

Automated Scripts
(e.g., SCL)



Procedure Lifecycle Development

- **Procedure Authoring Tool (PAT)**
 - Procedure authors currently use IPV (Licensed software & not easy to use)
 - Need an easy-to-use authoring environment
 - Need an easy method to add telemetry & commands
- **Procedure verification & validation (PV)**
 - Procedure verifiers are human intensive
 - Need for desktop verification tools to catch simple mistakes
- **Procedure Library Admin. (PLA)**
 - Configuration control works reasonably well today
 - Need to be integrated with Procedure Repository and Procedure approval system
- **Procedure Viewer/Executor (PVE)**
 - Integration with crew time and Caution & Warning system
 - Need to view/execute/track anywhere and any configuration (stationary, mobile, hand-free. Etc.)
- **Procedure training**
 - Integration with Workflow CR and procedure verification and validation
 - Measure and track performance





System Representation

- Procedure language describes how to operate any system. They do not describe the system itself
- System representation needs to define
 - Telemetry
 - Commands and command parameters
 - System hierarchy and classes
 - e.g., commanding the Orion Display Pages
- Must be available during procedure editing, validation and execution
- We selected XML Telemetric & Command Exchange (XTCE) -- an industry and NASA standard



Procedure Authoring Tool

The screenshot shows the PrIDE (Procedure IDE) application window. The main area displays a checklist entry titled "2.3 Turn on Lighting". The entry contains a single objective: "Light 1 - On". Below this, there are five steps listed under the heading "Light 2 - On":

- [RIU1] LIGHTING_LIGHT1_ACTUATOR equal LIGHT_OFF_STATE
- [RIU1] LIGHTING_LIGHT1_ACTUATOR equal LIGHT_ON_STATE
- [RIU1] LIGHTING_LIGHT2_ACTUATOR equal LIGHT_OFF_STATE
- [RIU1] LIGHTING_LIGHT2_ACTUATOR equal LIGHT_ON_STATE

To the right of the checklist is a "Palette" panel containing icons for "Select", "Step", "Substep", "If Statement", "Off Nominal Block", "Ground Block", and "Alternate Block". Below the palette is an "Instructions" section with icons for "Manual", "Call Procedure", "Go To", "Record Instruction", "Select Instruction", and "Command". Further down are sections for "Info" (Note, Caution, Warning, Figure, List, Table, Virtual Signs Table), "Advanced", and "Symbols".

A "Properties" panel at the bottom left shows the following table:

| Property | Value |
|-------------------------|---|
| 1. Required | |
| Command Id | \$system_id(CORE.LIGHTING.RIU1.LIGHT.1) |
| Parameter List | [0] arg1 LIGHT1 [1] arg2 ON |
| 2. Optional/Recommended | |
| Comment | |
| Extra Space Above | false |
| 3. Left Margin Entries | |
| Crew Members (label) | |
| Duration (label) | |
| Location (label) | |
| 4. Advanced | |

On the right side of the interface is a "System Representation Loader" panel showing a hierarchical tree of system components:

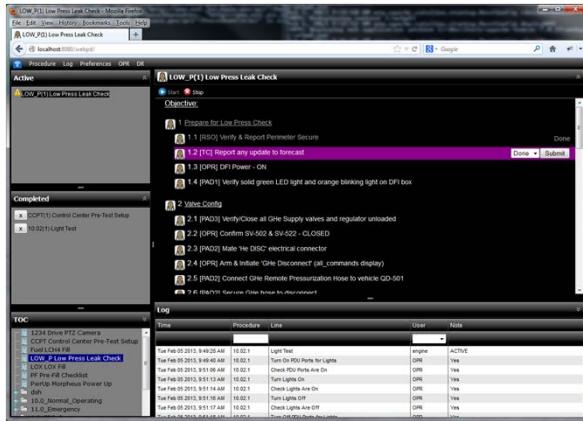
- HDU
 - AIRLOCK
 - COMMS
 - ECLSS
 - HUMFAC
 - TCS
- CORE
 - AVIONICS
 - CTRL1
 - CTRL2
 - RIU1
 - RIU2
 - RIU3
 - RIU4
 - COMMS
 - CRIO
 - ECLSS
 - FOOD
 - GEOLAB
 - HUMFAC
 - LIGHTING
 - MEDOPS
 - POWER
 - TCS
 - STRUCT
- HYGIENE
- XHAB
- DSH
- EXTERN

At the bottom left of the interface, the date "2/20/2014" is displayed.

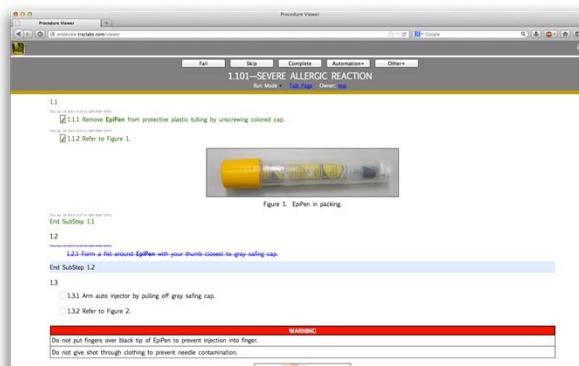


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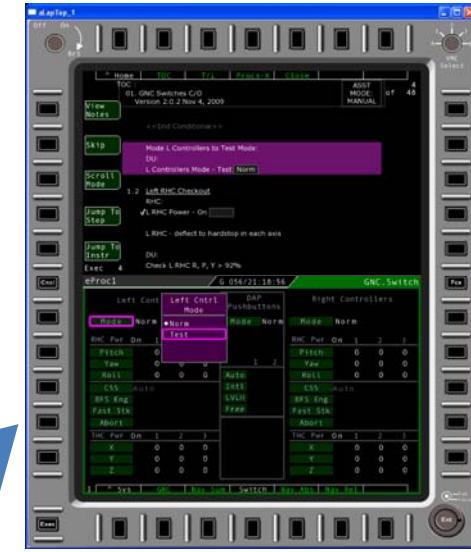
Procedure Viewer & Executor



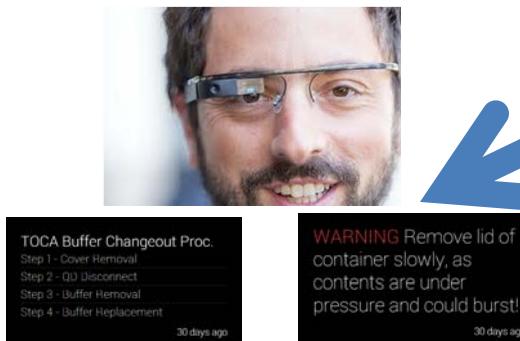
WebPD – Focus on C&W Integration



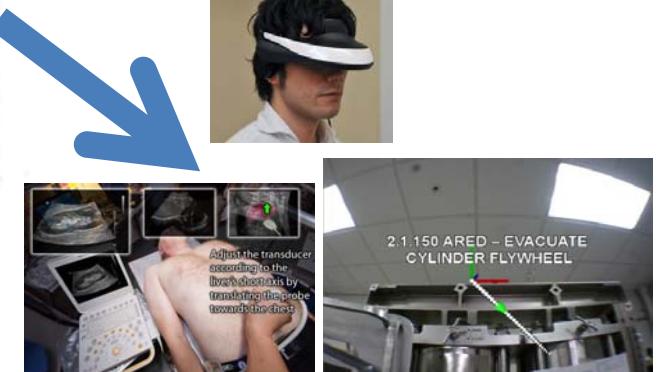
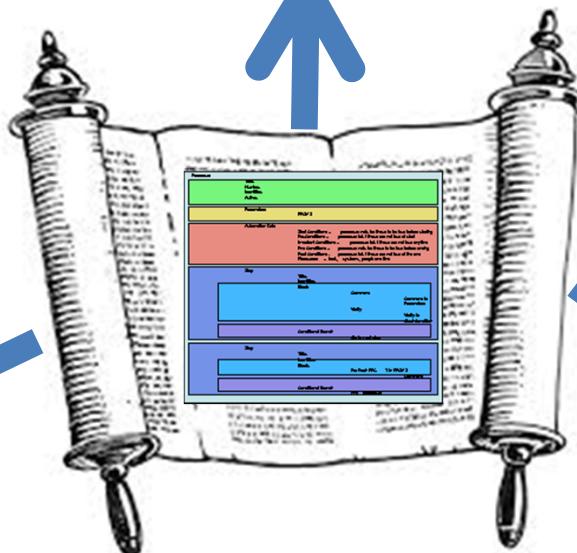
PRIDE View – focus on Procedure performance tracking



Orion eProc-Flight Deck – focus on Edge Keys Display & Keyboard-less interaction



Google Glass – Focus on Mobility & mobile interactions



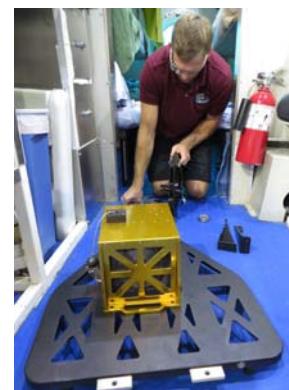
AR-eProc – Focus on mixed reality interaction

Capture Rich Procedure Content Once and Use It Everywhere!!



Miniature Exercise Device (MED):

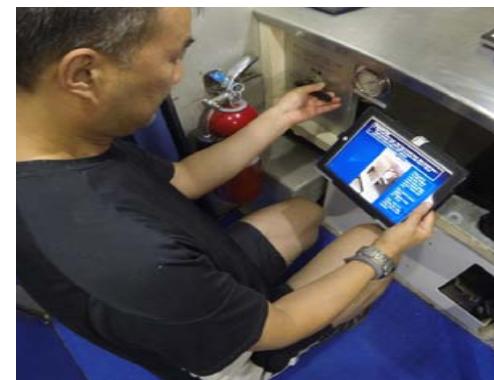
- a. Equipment Assembly Task
- b. Equipment Dis-Assembly Task

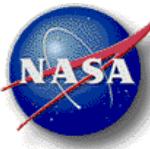


Just-in-time (JIT) training of a Sani-tank purge



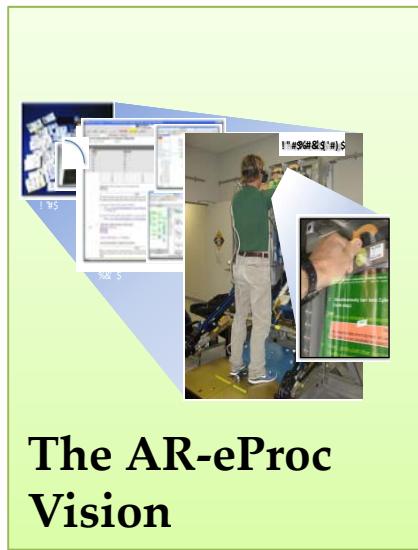
After the task was completed using the Google Glass – the same JITT material was viewed on an iPad





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Augmented Reality Training Assistance



The AR-eProc Vision

This section displays a collage of images illustrating the AR-eProc vision. It includes a large green arrow pointing right, several screenshots of mobile devices showing AR overlays for tasks like cylinder evacuation and ultrasound guidance, and a person standing in a lab setting with a monitor displaying a complex interface.



AR Ultrasound -
Autonomous
guidance



AR ARED – Augmented reality
Advanced Resistive Exercise
Device Cylinder Evac. Procedure



AR DSH Locator - Deep Space
Hab augmented reality assets
monitoring



AR TOCA - Augmented reality
Total Organic Carbon Analyzer
Buffer Change Out Procedure



Autonomous Operation

This section displays a collage of images illustrating autonomous operation. It includes a large green arrow pointing right, a screenshot of a mobile device showing a complex AR interface, and a person interacting with a white humanoid robot (GM-1) that is wearing a NASA and GM logo patch.